Know the Earth…Show the Way

Image Compression Status and Direction

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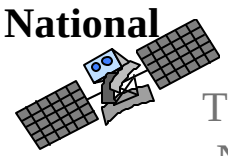
Evolution of Compression in the Architecture



National

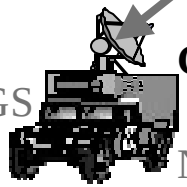
Downlink
Today: DPCM
Next: DPCM
Future: JPEG 2000

Tactical

Downlink
Today: Proprietary
Next: Proprietary and NITFS 2.0 JPEG
Future: NITFS 2.1 JPEG 2000

Video

Downlink
Today: Analog
Next: MPEG-2
Future: H.264, MJ2



DCGS

Ground Processing Station
Today: TFRD 4.3 DPCM
Next: NITFS 2.1 JPEG 2000
Future: JPEG 2000 (FF-TBD)

Ground Processing Station
Today: MPEG-2
Next: MPEG-2, H.263
Future: H.264, MJ2

Ground Processing Station
Today: TFRD 4.3 DPCM
Next: NITFS 2.1 JPEG 2000
Future: JPEG 2000 (FF-TBD)

Primary Dissemination
Today: TFRD 1.3 DCT, NITFS 2.0 JPEG DCT
Next: NITFS 2.1 JPEG 2000
Future: JPEG 2000 (FF-TBD)

Library Support
Today: TFRD 4.3 DPCM, 1.3 DCT, NITFS 2.0/2.1 (JPEG DCT, LBR DCT, RPF)
Next: Today + NITFS 2.1 JPEG 2000
Future: + JPEG 2000 with JPIP

Dissemination to Product Centers
Today: TFRD 2.3 DCT
Next: NITFS 2.1 JPEG 2000
Future: JPEG 2000 (FF-TBD)

NGA Raster Products
Today: NITFS 2.0 RPF (VQ)
Next: NITFS 2.0 RPF (VQ)
Future: NITFS 2.1 JPEG 2000

Users

JPEG 2000 will move up the chain

Once the leader . . .

- The Government was once the leader in digital imaging but now the consumer market spends significantly more money on digital imaging
  - The Government spent millions on the development of collection, storage and dissemination of digital imagery over the years, well before the internet and consumer digital cameras
  - Consumer cameras are bigger, better, and more affordable by everyone (X billion dollar business)
    - X Million Cameras and X million camera phones were sold in 2004
    - Average person takes 10 Pictures a week and prints 2 pictures per week

Continue to leverage consumer developments

Evolution of Still Image Compression Technology

- Digital Image Compression is a relatively young science but it may have hit its maximum potential with JPEG2000 for standard commercial imagery
  - 1951 DPCM (Shannon) and Huffman Codes
    - 1983-IDEX DPCM and 1989-AIRDPCM (30 Years)
    - The first step in image compression
  - 1974 DCT (Ahmed)
    - 1989-TFRD DCT and 1992-ISO JPEG DCT standard (15 Years)
    - 20 – 30 Percent increase in compression efficiency
  - 1984 Wavelets (Mintzer) and 1986 Arithmetic encoding (IBM)
    - 2000-JPEG 2000 standard (15 years)
    - 5 – 30 Percent increase in compression efficiency
  - No significant new technology in the last 15 years that could influence the start of a new still image compression standard

We do not expect a new or competing standard for over 20 years

Success of Involvement in JPEG 2000

- Several government/intelligence organizations were involved in the developing, evaluating, and documenting technology and requirements for JPEG 2000
  - A collaboration of several Government members and contractors in developing, evaluating, and documenting technology and requirements for JPEG 2000
  - Because of this, the international standard and the commercial profiles reflect meet the requirements of the intelligence community (IC)
- JPEG 2000 has been adopted by the national and tactical intelligence systems
  - NGA, NRO, Air Force, Navy, Army, . . .
- JPEG has been adopted by NATO
  - STANAG 4545 and 7023

Payback of Standards Investment

- Approximately $3 - 4M invested in support of JPEG 2000 development
  - Defined requirements and evaluated technology, and performed quality assurance on all aspects of the technology
  - IC's requirements were ingrained in the standard development
  - All commercial version meet the requirements of the IC
- Savings are significant once the commercial world adopts the technology
  - DDS DCT hardware board $1M (1990 money) versus JPEG 2000 hardware board $2K
  - Proprietary wavelet software development cost $750K – $1M JPEG 200 commercial software license $5K - $50K

Hundreds of Millions are saved through the use of SCOTS

Investing in technology development?

Three levels of technology development

- The commercial world has standardized technology which may have application to current or future problems
  - Action: Test technology for adoption
  - Investment: Test and demonstration contracts
  - Impact: 1 – 3 years before impacting architecture

Time Critical

The commercial world is developing standard technology

- Action: Actively participate in the standards development
- Investment: Technical person involved in standard development
- Impact: 3 – 5 years before impacting architecture

- The commercial world is not interested and is not investing into technology or applications
  - Action: Lead the technology development to meet requirements
  - Investment: Advanced IR&D with long lead time for standard
  - Impact: 7-12 years before impacting architecture)

Current Standards Developments

- JPEG 2000 Part 8:JPSEC Security Issues
  - Technology: Scalable encryption, Watermarking, . . .
  - Status: Working Draft (WD) to Committee Draft (CD) Vote
  - Time critical, we will not be able to influence it after Final CD (FCD)
  - Why they care: Copy write protection of images
  - Why we care: Security of classified data, information integrity, and downgrading

Time Critical

- JPEG 2000 Part 11:JPWL Wireless communication
  - Technology: Wireless interaction of JPEG 2000 packets
  - Status: Working Draft (WD)
  - Why they care: Phone cameras and web browsing over cell phones
  - Why we care: Delivery of data over the last tactical mile (wireless)

Time Critical

Advanced Standards Developments

Application Critical

MPEG Scalable Video Coding

- Technology: Advance Compression
- Status: Call for contributions
- Why they care: Interactive TV, scalable video on demand
- Why we care: Persistent surveillance applications, bandwidth mitigation

- Advanced Image Coding
  - Technology: Unknown – object based compression
  - Status: Call for investigation of technology
  - Why they care: General advancement of science
  - Why we care: Set testing procedure that is official
- JPSearch: Image and Metadata Search
  - Technology: Unknown – Metadata cataloging in MPEG-7
  - Status: Call for investigation of technology
  - Why they care: Internet searches, digital library archives for news
  - Why we care: Library search and archive

Commercial World Developed

- JPEG 2000 Part 6 Compound Documents
  - Technology: Segment image into text, image and graphics and compress separate
  - Status: Standard complete commercial application being sold
  - Why they care: Long-term storage of documents (memory is becoming cheaper than paper)
  - Why we care: ADRG and CADRG
  - Should be evaluated under Raster Re-engineering Study
- H.264 Motion Imagery Compression
  - Technology: Advanced motion compensation (Status: Standard complete-applications appearing in marketplace
  - Why they and we care: 50% increase in compression over MPEG-2
  - MISB developing standard based on technology

Commercial World Developed

- JPEG 2000 Part 9 JPIP: FDIS
  - Technology:JPEG 2000 interactive protocol
  - Status: Final Draft International Standard (FDIS) to International Standard (IS) in July, software available
  - Why they and we care: Interactive image libraries, dynamic image streaming
  - Current effort under GIAT demonstrating and testing technology
- JPEG 2000 Part 3 Motion
  - Technology: MPEG-4 file wrapper around JPEG 2000 files, first scalable video encoder
  - Status: Standard Complete, Commercial applications available
  - Why they care: Digital cameras, digital cinema
  - Why we care: Large frame video (greater than HDTV)
  - MISB has requested a white paper on applications

Non-Commercial Data types (commercial world will not invest $)

- MS/HSI Data Compression
  - Status: Technology and standard complete (JPEG 2000 Part 2), medical industry adopting for 3-D data, characterized impact to compression and exploitation
  - Action: Characterize cost in applications space (memory, speed, cost) versus impact
- Complex data compression
  - Status: No proven technology and no standards – Several proprietary algorithms claim success
  - Action: Develop testing procedures, define requirements, invest in the technology, evaluate JPEG 2000 for data type

Non-Commercial Data types (commercial world will not invest $)

- PI Imagery
  - Status: No specific compression, standard, characterization of data (spatial correlation, noise, MTF, SNR), and testing procedures
  - Action: Fully characterize data, develop testing procedures, define requirements
- Elevation data (DTED)
  - Status: No current standard or requirements for accuracy and testing procedures
  - Action: Define requirements, define testing procedure, test current compression standards for accuracy

Advanced Standard Work not progressing

Time Critical

- JPEG 2000 Part 10: 3D coding
  - Work Item was started by Dr. Chris Brislawn, Los Alamos National Laboratory for volumetric data
  - Several universities were involved
  - Los Alamos National Laboratory has cut all funding
  - This has applications in HSI, complex data, DTED, LIDAR, scientific data, medical data
  - This work item will fail if Dr. Brislawn does not secure funding
    - Los Alamos National Laboratory is willing to co-fund but will not be the only sponsor

Advanced Architecture Concepts

- JPEG 2000 technology will allow us to think outside the current architecture rules
  - Fast dissemination of data
    - After collection data is compressed and directly disseminated to user while data is being processed in the background (geo locate, geo reference, . . .)
    - Update to data is (warping coefficients, . . .)disseminated
    - Data is updated to product (CIB, . . .) at users site with information buy using current graphic cards
  - Distributed Libraries
    - Multiple library locations with different data at each location
    - Different resolution reside on different libraries
  - Wavelet exploitation
    - Advanced wavelet exploitation algorithms (warping, registration, change detection, motion detection, . . .)

Advanced Space Based Compression

- JPEG 2000 will be a requirement for future space based systems
  - Would produce better and more flexible compression over current DPCM algorithms
  - Enables direct dissemination to users
  - Advanced applications (only sending ROI of identified targets or moving targets)
  - Need to overcome the hurdle of designing Radiation-Hardened ASIC
  - 3 to 5 year development time
- NASA and CNSE (French NASA) could not make space qualified JPEG 2000 so they are developing a non-standard wavelet algorithm

Investment needs to be made to assure capability is ready

Conclusion/Recommendations

- Involvement in the standards at the requirements and technology stage is critical to assure the practical use of SCOTS products within the architecture
  - We need involvement with the JPEG 2000 Part 8:JPSEC and JPEG 2000 Part 11:JPWL standards activities.
  - Need an editor for the JPEG 2000 Part 10:3D.
- MS and Complex data compression needs to addressed
  - Define the requirements, applications, and capability
- It is critical that someone technical gets involved in scalable video coding work in MPEG early in the development stage.

Back up slides

Wavelet Compression Steps

- Technology, Events, and Standards Timelines
  - 1976 - Arithmetic Encoder (Rissanen, Pasco)
  - 1976 - Sub-band transforms (Croisier, Esteban, Galand)
  - 1980 - Trellis Coding (Finamore and Pearlman)
  - 1985-87 - QMF (Smith and Barnwell, mintzer, Vaidyanathan, Vetterli)
  - 1990 - Trellis Coding Quantization (Marcellin, Fisher)
  - 1990 - Reversible Wavelet transforms (Heer, Reinfelder)
  - 1992 - 9-7 Filter (Cohen, Daubechies, Feauveau)
  - 1993 - EZW-Embedded zero-tree of wavelet (Shapiro)
  - 1995 - CREW-Compression with Reversible Embedded Wavelets-(Zandi, Allen, Schwartz, Boliek)
  - 1996 - Lifting technology (Sweldens)
  - 1996 - SPIHT-Set Partitioning in Hierarchical Trees (Said and Pearlman)
  - 1998- EBCOT-Embedded Block Coding with Optimal Truncation (Taubman)
  - 2000 - JPEG 2000

JPEG 2000 History

- 1996 – JPEG-LS Evaluation (CREW Losses)
- 1996 – Start of new work item
- March 1997 – Call for contributions
- July 1997 - Kodak released Test Packet to 50 participants
- Nov. 1997 – Evaluation of 24 proposals
  - Kodak does the evaluation (Statistical, visual evaluation)
  - Wavelet TCQ wins
  - Core Experiment Group started
  - Requirements group started
- Martin Boliek named editor (Majani, Christopoulos – co-editors)
- March 1998 Verification Model (VM) 0
- July 1998 VM2 – Addition of integer based wavelets, tiling, ROI, Error resilience
- November 1998 VM3 Addition of EBCOT
- March 1999 – VM4 MQ coder
- July 1999 – VM5 Codestream syntex
- November 1999 – VM6 Canvas Coordinate Systems, better Error detection
- VM6 – 9 Part 2 – Selectable wavelets, multiple component compression, file format,

Compression Rate Improvement Over Time

(Constant Quality)